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MACROINVERTEBRATE COMMUNITY STRUCTURE
AT SELECTED SITES ON THE UPPER
BUFFALO RIVER

FINAL REPORT

MACROINVERTEBRATE COMMUNITY STRUCTURE AT SELECTED SITES ON THE UPPER BUFFALO RIVER

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Buffalo National River

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EXECUTIVE SUMMARY

The Ozark Mountain region of Missouri and Arkansas represents one of the largest concentrations of relatively undisturbed, free-flowing streams remaining in the contiguous United States. Among the most pristine streams within this area is the Buffalo River and its tributaries. However, recent physicochemical monitoring of water quality suggests that some tributaries and mainstream reaches of the Buffalo National River are receiving substantial inputs of organic pollution. During a 4-year period (1985-1988), fecal coliform levels progressively increased at the downstream end of Boxley Valley. Biotic impacts associated with this decline in water quality are unknown. The primary objective of this investigation was to establish baseline information on the stream macroinvertebrate fauna that could be used in assessing biotic impacts of anthropogenic disturbances. A secondary objective was to compare the effectiveness of a variety of biological water quality indices in assessing impacts if they have occurred.

Samples were collected at four sites on six dates between June 1990 and March 1991 using standard benthic sampling techniques. Two sites were located on the main channel; two on tributaries. Mainstream sites included a near-pristine reach (UBV) located at the upper end of Boxley Valley where the river flows from the Upper Buffalo Wilderness Area and a more disturbed reach (PON) at the lower end of the valley near Ponca, a site where high levels of fecal coliforms have been reported. Tributary sites included Cecil Creek (CEC), a relatively undisturbed head-water stream, and Mill Creek (MIL), a small stream receiving effluent from an amusement park (Dogpatch, U.S.A.) and numerous residences built along its banks.

Samples were sorted in the laboratory, identified to the lowest taxon possible, and each taxon enumerated. Data on species (taxon) abundance were analyzed using a number of techniques including species richness (raw richness, rarefracted richness, and Margalef's Index), species diversity (Shannon's Index, Simpson's Index, and Hill's Numbers), community composition (percentage Ephemeroptera, Plecoptera, and Trichoptera (EPT) and ratio of Ephemeroptera, Plecoptera, and Trichoptera to Diptera (EPT:D)), and Hilsenhoff's Biotic Index. Community composition among all sites was compared using chord distance dissimilarity analysis and analysis of functional structure.

A total of 93 taxa of aquatic insects representing nine orders and 45 families were collected from the Upper Buffalo River. Members of the orders Ephemeroptera, Plecoptera, Trichoptera, and Diptera accounted for over 90% of specimens collected on virtually all dates and at all sites. Included among these were a variety of genera that may represent potentially valuable indicator organisms.

Results of chord distance analysis and functional structure suggest that two distinctly different stream types were sampled; UBV and PON formed one pair, the two tributary sites another. Natural differences in the physical and biotic characteristics of these two stream types are large, restricting meaningful comparisons to within tributary and mainstream pairs. For all indices, values suggesting greater community

health were obtained at the more pristine sites (UBV and CEC). Index values obtained for MIL were much lower than those at CEC, suggesting relatively low community health at MIL. Values obtained from PON were slightly lower that those at UBV, but these differences are accentuated when considering that natural increases in these values should have occurred at PON.

These results suggest that the Buffalo River system harbors one of the most diverse aquatic insect assemblages reported from the Ozarks. Its protected status and historically low levels of anthropogenic disturbance have preserved the biotic integrity of much of the watershed. However, specific tributaries and portions of the main channel have experienced some habitat degradation as has been previously indicated by physicochemical water quality monitoring. The results of this investigation suggest that correlative changes in the biotic complexity at these disturbed sites have occurred. The aquatic insect community at Mill Creek has been impacted severely. That of the lower end of Boxley Valley also has been impacted, but to a lesser extent.

Conclusions concerning water quality based on the results of this investigation correspond with those produced through physicochemical techniques, demonstrating the complimentary nature of biotic and physicochemical water quality monitoring. Information gained through physicochemical methods facilitate the identification of areas experiencing pollution and the types of disturbance occurring at these sites. Biological information provides evidence that negative impacts have occurred and appears useful in assessing the magnitude of disturbance. Both methods are essential for an effective water quality monitoring program.

Based on these results, the following recommendations are extended:

1. Studies should be undertaken to determine the impact of poor water quality in Mill Creek on the Buffalo River proper and to verify the results obtained in Boxley Valley.

2. Biological information should be collected at additional sites, both pristine and disturbed, in order to develop a firm data base needed for establishing a biological monitoring system. During this developmental phase, samples should be collected at minimum four times yearly (preferably six) and specimens be identified to the species level when ever possible.

3. Comparisons between the results obtained using Rapid Bioassessment (RBA) techniques and standard benthic sampling methods should be undertaken in order to determine if RBA sampling techniques can be used. These techniques would save both time and money when the monitoring system is begun.

4. Following the collection of sufficient baseline data (2-3 years), a biotic index similar to that of Hilsenhoff's should be implemented as a regular component of the water quality monitoring program for the Buffalo National River.

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The Ozark Mountain region of Missouri and Arkansas represents one of the last large concentrations of relatively undisturbed, free-flowing streams remaining in the continental U.S.A. (see Benke, 1990). Located within this mountainous region are two National River systems, numerous Scenic rivers, and a variety of high-quality streams that have yet to be protected. Surprisingly, few detailed, community-level investigations have been conducted on the aquatic insect fauna of streams in this region. This lack of study represents an under utilization of a valuable resource and has resulted in numerous problems for area resource managers. Like many parts of the country, the Ozarks are being developed at an unprecedented rate. Streams are being impacted negatively by a variety of anthropogenic disturbances associated with this development. Because baseline data are lacking, resource managers have too little information to use during impact assessments or on which they can base well-founded management plans and biological monitoring programs.

Approximately 30 published investigations on Ozarkian stream communities have been undertaken. However, these are variable with regard to their usefulness to resource managers. Many provide too little taxonomic information, identifying organisms only to the ordinal or familial levels (e.g., Sullivan, 1929; Aggus and Warren, 1965; O'Connell and Campbell, 1953). Others are surveys to specific taxonomic groups that provide little indication about community structures of streams (e.g., Harp and Richett, 1977 concerning dragonflies; Kittle, 1980 on water striders; Unzicker et al., 1970 and Bowles and Mathis, 1989 for Trichoptera). In Arkansas, most are confined to the northeastern or northwestern portions of the state near

institutions conducting aquatic research (Arkansas State University, Jonesboro and University of Arkansas, Fayetteville).

Recent physicochemical water quality monitoring on the Buffalo National River, one of the Ozarks' most pristine watersheds, has shown a disturbing trend of increasing levels of fecal coliforms at some areas within the park (see Mott and Apel, 1988). These increased levels suggest higher amounts of organic waste entering the system from nonpoint discharges. Over the past 4 years, coliform levels have increased substantially in the area around Boxley Valley; a number of tributaries also show elevated fecal coliform levels. Although these levels are lower than those reported for other area streams, resource managers for the park questioned the possibility of biological impacts associated with this decline in water quality. They expressed an interest in developing a biological water quality monitoring program to supplement their physicochemical program. Unfortunately, detailed baseline data on the aquatic macroinvertebrate community of the stream are lacking. Early investigations (Schmitz, 1974; Kittle, 1975) yielded only 42 taxa, most identified to the generic level. The primary objective of this investigation was to compile baseline data on the benthic aquatic insects of the Buffalo River. A secondary objective was to test a variety of biological monitoring techniques at both relatively pristine and more disturbed sites to determine if negative biotic impacts could be detected.

The use of aquatic macroinvertebrates for water quality monitoring has received increasing amounts of attention over the past two decades. Biological monitoring has distinct advantages over classical physical and chemical techniques because aquatic organisms act as

continuous monitors of water quality (Berkman et al., 1986; Chandler, 1970; Goodnight, 1973). More traditional methods measure water quality only at the time that samples are collected and may fail to detect pollutants that occur at low concentrations or enter as periodic fluxes. Also, they analyze for a limited number of compounds and say nothing about biotic effects of the perturbation.

Investigations using biological monitoring can be divided into two broad categories: studies using indicator species and studies of community structure (Resh and Unzicker, 1975). The first approach involves the identification of pollution-tolerant and intolerant species whose presence or absence give some indication of water quality at particular sites. This approach has been adopted by most European and Soviet hydrobiologists, but is not without problems; the simple presence or absence of a given species can be misleading. Pollution-tolerant species may occur at low densities even in the most pristine conditions; likewise, low densities of pollution-intolerant species may occur in polluted sites (Chandler, 1970; Wilhm, 1970). Specific indicator organisms may be intolerant to one pollutant or disturbance and tolerant or insensitive to others (Cairns, 1977).

The second approach involves the determination of community organization as indicated by species richness and the relative abundance of each species (or other terminal taxon) (evenness). These data are used to calculate various diversity indices that indicate the complexity of the system. The basic premise of these types of studies is that, in most systems, anthropogenic disturbances reduce species diversity. In otherwise similar systems, those experiencing larger magnitude disturbances should have lower species diversities than less

disturbed systems. This approach suffers from a number of problems including the selection of the most informative and sensitive index (Robinson and Sangren, 1984; Washington, 1984) and interpretation of the calculated value (Resh and Unzicker, 1975; Hughes et al., 1986).

Modifications of species diversity techniques that incorporate indicator organism concepts are termed biotic indices. Included among these are Hilsenhoff's Biotic Index (HBI) and various indices based on community composition of the pollution-intolerant insect orders (e.g., Ephemeroptera, Plecoptera, and Trichoptera) versus pollution-tolerant orders (e.g., Diptera) (percent EPT; EPT:D). The most successful biotic index developed to date is Hilsenhoff's Biotic Index for organic stream pollution in Wisconsin (Hilsenhoff, 1982, 1987). This index assigns specific weighted factors to each taxon according to their known pollution tolerances and then uses these adjusted values in calculations similar to those for species diversity. This group of indices has been quite successful in the areas where they have been designed and implemented. However, critics, including the EPA, suggest that they are of limited value being both pollution and geographically specific (Washington, 1984).

STUDY AREA

Two pairs of sites were selected based on data concerning water quality (see Mott and Apel), and stream size and geomorphology. Each pair consisted of one site with relatively higher water quality and one with lower quality. Main channel sites included the relatively pristine reach in the upper Boxley Valley (UBV) just below the boundary of the Upper Buffalo Wilderness Area and two more disturbed sites at the downstream end of the valley near Ponca (PON-A and PON-B) (Fig. 1). Tributary sites included the relatively pristine Cecil Creek (CEC) near Erbie and the more-disturbed Mill Creek (MIL) near Pruitt (Fig. 1).

The upper Boxley Valley site has a watershed area of approximately 34,000 acres, a relatively high gradient, large substrates, and is largely uncanopied due to an erosional "blow-out" along the outer portion of a meander. Mott and Apel (1988) reported fecal coliform levels ranging between 2-567/100 mL for that year and a geometric mean (G-mean) of 14/100 mL; G-mean values for 1985-1987 were 2-4/100 mL. During this investigation, surface flow was always present although much diminished during the summer.

Two sites were sampled at the lower end of Boxley valley. One site is located approximately 3-miles upstream from Ponca bridge on property leased to Hubert Ferguson (PON-B) and was sampled during June, July, and August. This site is similar to the UBV site in having large substrates, similar flow patterns, and extensive bank erosion. The area drained by the river at this location represents approximately 58,000 acres. The other site (PON-A) is located at the Ponca low-water bridge and was sampled during November, January, and March. PON-B has

a drainage area of approximately 61,000 acres and a visibly lower gradient, smaller substrate size, and more permanent flow than either of the two more upstream sites. During 1988, fecal coliform levels at PON-B were 10-540/100 mL with a G-mean of 44/100 mL; G-mean values for 1985-1987 were 6-16/100 mL.

Cecil Creek is a small head-water stream located in a protected watershed near Erbie. Samples were collected immediately downstream from the low-water slab approximately 1 mile above its confluence with Buffalo River. Water quality analysis from CEC (see Mott and Apel, 1988) suggests relatively pristine conditions; fecal coliform levels during 1988 ranged between 0-36/100 mL with a G-mean of 6/100mL. Stream gradient is visibly high, substrates large, and flow intermittent during the summer months. The drainage area of this stream equals approximately 13,000 acres.

Samples from Mill Creek were collected immediately upstream of the low-water bridge crossing the creek near the Pruitt access area. Located downstream from Dogpatch (an amusement park) and a number of residences, water quality analysis suggests that MIL receives higher levels of fecal contamination than does the Cecil Creek site; fecal coliform levels of 2-247/100 mL (G-mean = 15/100 mL) were reported during 1988 (see Mott and Apel, 1988). The watershed size of MIL equals approximately 12,500 acres; substrates consisted almost exclusively of gravels with some larger cobbles, and flow remained relatively stable throughout the investigation.

METHODS

Six 0.1-m^2 benthic samples were collected at each site (except Pon-A and PON-B) on each of six dates (June, July, August, and November 1990; January and March 1991) using a modified Hess sampler equipped with 254-um mesh. Collections were made at PON-B during June, July, and August and PON-A during November, January, and March. Samples were preserved in the field with Kahle's solution and transported back to the laboratory for sorting and identification. Specimens were identified to the lowest taxonomic level of which I was capable using a variety of keys including: Merritt and Cummins (1984) for a wide variety of taxa to genus, Stewart and Stark (1988) for genera and some species of Plecoptera, Wiggins (1977) for genera of Trichoptera, Ross (1944) for species-level determinations in selected trichopteran genera, Bednarik and McCafferty (1977) for species in the mayfly genus Stenonema, and Provonsha (1990) for species in the ephemeropteran genus Caenis.

For analysis, data from the six samples collected at each site on each date were pooled to create one large sample. Data from PON-A and PON-B were combined and treated as a single site (PON). Richness and species diversity indices were calculated using the SPDIVERS.BAS and RAREFRAC.BAS programs provided with Ludwig and Reynolds (1988). Percentage Ephemeroptera-Plecoptera-Trichoptera (EPT) and ratio of Ephemeroptera-Plecoptera-Trichoptera to Diptera (EPT:D) were calculated on pooled data for each site over the entire sampling period.

Hilsenhoff's Biotic Index (HBI) was calculated on pooled data collected during November-March as suggested by Hilsenhoff (1987). For a few taxa, pollution tolerance values in Hilsenhoff (1987) had to be

adjusted because of lower taxonomic refinement in the present study. For instance, 10 species of the mayfly genus Baetis were identified by Hilsenhoff (1987) and assigned pollution tolerance values of 2-6. I could not identify members of this genus to species and applied the mean value of Wisconsin species (X = 5) to the entire genus. Other taxa for which similar adjustments were necessary included the mayfly genus Pseudocloeon (adjusted value = 4) and the dipteran family Chironomidae (adjusted value = 5). Although this potentially is a significant bias to these calculations and renders the final value only questionably comparable to those in Hilsenhoff (1987), I believe that the ranking produced between the paired sites is accurate because of faunistic similarities within the pairs.

Functional group analysis (Merritt and Cummins, 1984) and chord distance (SUDIST.BAS; Ludwig and Reynolds, 1988) were performed among the four sites to determine similarities between the sites.

RESULTS

Over 17,500 specimens of benthic aquatic insects representing 93 taxa including nine orders and 45 families were collected and identified to the lowest taxonomic level possible (Table 1). Samples collected in June at the Boxley site and at Steel Creek contained 3 additional taxa (Order Trichoptera; Ironoquia, Ochrotrichia, Pycnopsyche) that were not included in the analysis, raising the total number of taxa collected in benthic samples to 96. Three groups of Diptera could be identified only to the familial level (Families Ceratopogonidae, Chironomidae, and Tabanidae); 75 taxa were identified to genus, and 13 to species. Two species in the stonefly genus Neoperla were indentifiable only in later instars; abundances of these two species were pooled in the analysis. Likewise, two species in the mayfly genus Stenonema, S. pulchellum and S. terminatum, exhibited broadly overlapping morphology and could not always be separated from one another; for analysis, abundances of these two species were pooled. Orders exhibiting the greatest richness included the Ephemeroptera (24 terminal taxa), Trichoptera (18 terminal taxa), Plecoptera (17 terminal taxa), and Diptera (15 terminal taxa).

Individual taxa lists with abundances of each taxon for the four sites are given in Tables 2-5. Upper Boxley Valley (UBV) and Cecil Creek (CEC) had the highest raw species richness with 69 taxa each. The Ponca (PON) and Mill Creek (MIL) sites had lower species richness with 62 taxa each. Samples collected during May at UBV would have increased richness at that site to 73. Of the 93 taxa collected, 42 occurred at all four sites. Each site had a number of unique taxa (UBV, 5 taxa; PON, 5 taxa; CEC, 4 taxa; MIL, 5 taxa). Six taxa were

collected only at UBV and CEC, but not the two other sites; 5 taxa were collected only at PON and CEC and two taxa each only at PON/MIL, UBV/MIL, and MIL/CEC.

The five most abundant taxa at UBV (Table 2) were (in descending order of abundance) Caenis anceps, Chironomidae, Isonychia spp., Pseudocloeon spp., and Cheumatopsyche spp.; these five taxa accounted for 55% of the individuals collected at UBV. At PON (Table 3), the five most abundant taxa were Chironomidae, Caenis anceps, Stenonema mediopunctatum, Isonychia spp., and Cheumatopsyche spp. (55 % of individuals collected). At CEC (Table 4), Chironomidae, Pseudocloeon spp., Leuctra sp., Agapetus sp., and Isoperla spp. (57% of individuals collected). The five most abundant taxa at MIL comprised 75% of the individuals collected (Table 5) and included Chironomidae, Baetis spp., Pseudocloeon spp., Cheumatopsyche spp. and Isonychia spp.

Communities at all four sites are dominated by members of 4 taxa, Ephemeroptera, Diptera, Trichoptera, and Plecoptera, both on individual sampling dates (Fig. 2) and for yearly totals (Fig. 3). These four orders accounted for over 90% of all individuals collected on all dates at all sites with the exception of the August sample at PON when members of the Order Coleoptera comprised almost 15% of the sample (Fig. 2). Communities at UBV, PON, and MIL were dominated by members of the Order Ephemeroptera; dipterans were the second most important group followed by Trichoptera and Plecoptera (Fig. 3). The CEC community was comprised of nearly equal proportions of each of these groups (Fig. 3).

Results of chord distance dissimilarity analysis suggest that the two tributary sites (CEC and MIL) are more similar to one another than

either is to the main channel sites (UBV and PON) and vice versa (UBV-PON, 0.44; UBV-MIL, 0.71; UBV-CEC, 0.84; PON-MIL, 0.76; PON-CEC, 0.87; MIL-CEC, 0.67). Functional group composition (Fig. 4) of UBV, PON, and MIL were similar and quite different from that of CEC. The proportion of the communities composed of shredders is at least 3 times higher at the two tributary sites than at the main channel sites. Proportional abundance of predators at the two pristine sites was twice that at the disturbed sites.

Seasonal patterns in raw species richness (Fig. 5) differed between tributary and main channel sites. At both CEC and MIL, species richness was highest during March and lowest in November. Values obtained during summer months (Jun-Aug) were relatively stable. Within this pair, richness was greatest at CEC on all dates. At UBV, richness was highest during March and lowest during June. At PON, peak richness occurred both during July and March and was lowest during June. With the exception of the July sampling date, richness within this pair was always greater at UBV than PON.

Seasonal patterns of Margalef's Index (Fig. 6) largely paralleled those seen in raw richness. Richness at tributary sites was greatest during the winter months (January and March) and lowest during November. Values obtained from CEC always were above 4.0, but those obtained at MIL were as low as 2.3. At the main channel sites, Margalef's richness was highest during March, and were consistently higher at UBV than PON with the exception of the July sample. At UBV, lowest values were obtained during July and August (4.4). The lowest value obtained at PON was 3.0 during June.

Seasonal patterns in species diversity (Figs. 7 and 8) varied from

site to site. At CEC, diversity increased throughout the summer and fall, peaking during January before falling off in March. Values at MIL, vacillated throughout the year; highest diversity occurred during June and August, lowest diversity in November. Within this tributary pair, diversity was higher at CEC than MIL on all dates except for June. Species diversity at both main channel sites was highest during March and lowest during June. Diversity was higher at UBV during June, July and November and at PON during August, January, and March. Generally, the seasonal changes at PON were much more variable than those seen at UBV.

Results of nine methods analyzing community structure are presented in Table 6. Comparing within the two stream types, all nine techniques suggest relatively higher levels of community health at the pristine site than at the disturbed site. However, the magnitude of differences between the tributary sites is much larger than that between main stream sites. Comparing among all sites, values suggesting highest community health were obtained either at CEC or UBV; with the exception of richness (NO and RR), lowest values for all methods occurred at MIL.

DISCUSSION

Over the past two decades, the use of biological information for water quality monitoring has become increasingly popular. However, much still remains to be learned about the proper application and interpretation of this knowledge. A wide variety of potentially valuable indices of water quality have been proposed, but, with regard to aquatic macroinvertebrate community structure, no one index has received overwhelming support. This lack of standardization makes comparisons between the results of different studies virtually impossible. Further complicating the situation is the widely differing degrees of taxonomic refinement among published reports. Many authors identified organisms only to upper-level taxa (order or family) while others classified to the species level. Still, I have tried to make comparisons when ever possible. When raw data were available, I have adjusted for taxonomic refinement and analyzed the data using methods of the current investigation.

One of the more important rules in biological monitoring of water quality is to compare only among those sites that are physically similar. In lotic ecosystems, physical characteristics present a gradient of change from headwaters to mouth; corresponding changes occur in the biota (Vannote et al., 1980). For instance, physical characteristics (e.g., temperature, discharge, water chemistry) fluctuate more widely at midreaches of a stream and provide a greater number of temporal and spatial habitats than at either headwater or downstream reaches. Correspondingly, species diversity is higher in the midreaches than at either upstream or downstream sites. In order to detect impacts of a particular disturbance on a stream community,

sampling must be conducted at two sites, one pristine and one impacted; natural differences between these sites should be minimal. While in theory, this might seem easy, in practice, considerations such as site accessibility must be taken into consideration.

Site pairings for this investigation were based on physical attributes of each site and the results of chord distance and functional group analysis. Water temperatures, acreage in watershed, width of channel, and amount of canopy were similar at CEC and MIL and suggest that these two streams are headwater in nature. Physical characteristics at UBV and PON also were similar and suggests that the river at these sites is a medium-sized stream. Although watershed size nearly doubles between UBV and PON, Hughes et al. (1986) suggest that valid comparisons can be made between streams having less than a magnitude of difference in flow. Chord distance values among all possible pairings suggest that UBV and PON are more similar to one another than either is to the other sites. The same is true for CEC and MIL although the degree of similarity is much less between these as compared to UBV and PON. The functional group compositions within the UBV/PON pair are similar, but those of CEC/MIL are very different; MIL appears more similar to the two main channel sites than to CEC. However, the higher proportion of shredders at MIL (3X higher than at UBV and PON) indicates that this site has definite headwater stream attributes. Shredding organisms consume course particulate organic matter (CPOM) such as leaves which are a more abundant food resource in headwater streams than in downstream reaches. Because of these differences in CPOM abundance, shredders are relatively more numerous in head-water streams than at downstream sites (Vannote et al., 1980).

Differences observed in the functional group composition between CEC and MIL may be the result of differing levels of anthropogenic disturbances between the two sites. The large number of residences located along Mill Creek where it parallels Highway 7 suggests that this stream receives considerable amounts of minimally treated sewage. If significant amounts of organic waste enter this stream, pollution-intolerant species might be eliminated resulting in an overall change in functional group composition. These results suggest that MIL and CEC and UBV and PON represent two distinct pairs quite different from one another. Therefore, comparisons of the various indices which follow should be made only among pairs and not between them in most instances.

Species Richness

The usefulness of species richness in water quality monitoring is unsettled. Theorists suggest that highly-impacted communities with low diversity and evenness can have moderately high richness. In such instances, decisions based on richness alone could lead to incorrect conclusions. However, richness is an important attribute of any community that when viewed in the context of other attributes, provides a good deal of information. Because richness increases with increasing sample size, its value as a comparative index is limited unless corrections are made for differences in sampling intensity. I used two basic techniques for correcting raw richness, Margalef's Index and rarefraction analysis. Margalef's Index compensates for differences in sample size by dividing the number of taxa by the natural log of the sample size. Rarefraction analysis produces mathematical distributions of data sets with unequal sample size and then allows for the

extrapolation of richness at equal sample sizes.

Values of raw species richness obtained during this study are among the highest reported for Ozark streams. McCraw (1978) reported 57 taxa of aquatic insects from six collection stations on Clear Creek near Fayetteville. However, recent refinements of systematic keys to a variety of taxa allowed me to identify some taxa to lower levels; adjusting for these taxonomic improvements, the maximum richness for the Clear Creek study was 72 species. Cather and Harp (1975) reported 78 taxa of insects collected during July-October in benthic samples from two sites on Janes Creek, a clear spring-fed Ozarkian stream in northeastern Arkansas. Unlike the present study, they collected from both riffles and pools and identified chironomids, many beetles, and members of the mayfly genus Baetis to species. Removing those species collected only in pools and taxa identified to lower levels than in the present study, approximately 40 taxa were collected using methods equivalent to those during this study (but during a more limited time period and at fewer sites). Brown et al. (1983) reported 21 taxa from the White River during an investigation of the impact of organic sewage on macroinvertebrate community structure and leaf processing rates. Seventeen taxa occurred above the sewage treatment plant discharge; only 7 immediately downstream from the discharge. Progressively higher numbers of taxa occurred at two sites located further downstream. These values are much lower than those obtained during the present study, but they represent data from a single date on a stream that is more highly disturbed (even above the point discharge) than the Buffalo River. They do, however, demonstrate the significant impact of organic pollution on richness. Robison and Harp (1971) reported 17 taxa of

insects from the Strawberry River but did not identify specimens below the generic level.

Ryck (1973) collected benthic samples from a large number of streams in eight watersheds of the Ozark Mountains in Missouri, but provided taxonomic data only for the mayflies and stoneflies. Twenty-eight "common" taxa of mayflies (identified mostly to species) and 21 "common" taxa of stoneflies (all but members of the genus Allocapnia identified to species) were reported from these streams. Ryck's definition of common is somewhat vague. I am not certain whether his lists included all species collected during the study or truly only the common taxa. Nevertheless, the 25 taxa of mayflies and 17 taxa of stoneflies collected during this investigation apparently represent high species richness for these orders. As specimens are identified to the species level, these numbers should increase considerably.

Seasonal patterns in raw richness observed during this investigation suggest that this community attribute may have some value as a discriminator of environmental quality because on almost all dates sampled, richness was higher at the more pristine sites than at more disturbed sites. However, these values have not been adjusted for differing sample sizes which may pose a significant bias that must be taken into consideration.

Margalef's Index was first proposed as a diversity index, but more recently has been categorized as an index of richness. It is the only index that has been used widely by other studies on aquatic insect communities in Ozarkian streams. Ryck and Fuchs (1973), working on stream ecosystems in Missouri, found that reduced values of this index

in polluted streams correlated strongly to reductions in the numbers of taxa of pollution sensitive mayflies and stoneflies ($r = 0.92$). Ryck (1973) monitored changes in Margalef's richness at a variety of stream sites, some pristine but others impacted by sedimentation, organic waste, or toxic compounds. He suggested that unpolluted lotic ecosystems exhibited values of 4.0-10.0 for Margalef's Index and had a minimum of eight taxa of mayflies and stoneflies; slight to moderate pollution yielded values of 3.0-3.9 with 4-7 taxa of mayflies and stoneflies; heavy pollution, 2.2-2.9 with 1-4 taxa of these groups; and gross pollution, values below 2.2 and lacked mayflies and stoneflies. Duchrow (1982, 1983), working in the mineral mining area of southeastern Missouri, suggested that the number of mayfly and stonefly taxa associated with the various levels of pollution should be changed to 10 or more for unpolluted sites, 5-9 for sites with index values of 2.2-3.9, and 4 or fewer for streams with a value below 2.2.

During the present investigation, values of 4.0 or greater were obtained at both pristine sites on all collection dates. PON exhibited values of 3.0-3.9 during June, August, and November, but values were above 4.0 during July, January, and March. MIL had values above 4.0 during January and March, values of 3.0-3.9 during June and August, and 2.2-2.9 in July and November. Obviously, a natural cycle of species richness occurs in communities on the upper Buffalo River; richness is lower during summer and fall months and higher during winter and spring. Because values above 4.0 occurred during the winter and spring at disturbed sites, use of Margalef's Index should be confined to simultaneous comparisons over an entire year between sites experiencing differing levels of disturbance. Rankings produced from such

comparisons, both at a given date and over all dates, should allow for the identification a streams experiencing higher levels of anthropogenic disturbance.

The number of mayfly and stonefly taxa present at these sites are much higher than the minimal numbers proposed by Ryck (1973) and Duchrow (1982, 1983). Throughout the six collection dates, only MIL had less than 10 taxa of mayflies and stoneflies, and then only on one date. Trends of changing richness with changing levels of disturbance based only on the number of mayfly and stonefly taxa are not evident. However, if the number of caddisfly taxa present on each date is added to these data, a strong trend becomes evident with UBV and CEC having higher richness of these three orders than either of the two more disturbed sites.

Rarefracted richness values were calculated only on yearly totals for each site. Because sample sizes were nearly identical between all sites, only small changes in species richness occurred producing trends identical to those seen for raw species richness.

Species Diversity

Species diversity indices integrate species richness and evenness into a single value. Although widely used by research biologists, the value of species diversity indices for biological water quality monitoring is questionable. Among those using these indices of community structure, Shannon's Index (H') is most preferred. Opponents of diversity indices suggest that they are overly sensitive to changes in the abundances of dominant species, but are relatively insensitive to changes observed in rarer species. Considering this, diversity could increase at a given site when evenness increased, but richness

decreased. Others suggest that too much information is lost by compressing so much data into a single value. Like other community attributes used as environmental discriminators, these are most useful when viewed in the context of other data on community structure.

Four diversity indices were calculated at all sites for each sampling date. Theoretically, Shannon's Index ranges from 0 to infinity although values typically range between 1 and 3; increasing values indicate increasing diversity. Simpson's Index ranges between 0 and 1 with lower values indicating higher richness. Values of Hill's Numbers 1 and 2 equal the number of abundant and very abundant species in a community; higher values indicate higher diversity.

No distinct seasonal patterns in diversity were observed using these four indices. None showed consistent differences between UBV and PON from date to date, but, when comparing between CEC and MIL, a strong pattern of lower diversity at MIL is evident. Calculations on pooled data produced rankings between sites similar to those derived from other indices. These results suggest that the use of diversity indices for environmental discriminators may be helpful only when comparing between relatively-pristine and highly-impacted sites or when working with pooled data sets from an entire collecting season.

EPT, EPT:D, and HBI

These three indices rely on some knowledge about the pollution tolerances of various taxa within a community. The usefulness of percent Ephemeroptera-Plecoptera-Trichoptera in the community (EPT) and ratio of Ephemeroptera-Plecoptera-Trichoptera to Diptera (EPT:D) in identifying effects of organic pollution are based on observations that members of the first three orders, as a group, include most of the

pollution-intolerant species in lotic ecosystems; on the other hand, the order Diptera includes many pollution-tolerant taxa. Like results obtained with diversity, EPT and EPT:D exhibit considerable variation throughout the year at a given site and are most useful in analyzing data for the entire year. Values of both indices calculated on year-in totals were higher at the two pristine sites suggesting greater abundance of pollution-intolerant taxa at these sites as compared to MIL and PON.

Hilsenhoff's Biotic Index (Hilsenhoff, 1987) was developed for monitoring the impacts of organic pollution on lotic ecosystems in Wisconsin and has been tremendously successful in that state. Detailed taxonomic knowledge of the aquatic insect fauna and their pollution tolerances are needed to use this system to its fullest. Although our knowledge of the aquatic insect fauna of Arkansas is largely incomplete and use of such an index has some biases, I included HBI to demonstrate its potential as an environmental discriminator. Values yielded by this index produced rankings similar to other indices, but on the basis of fewer collections. With 2-3 years of work, I believe that such an index could be developed for the Buffalo River.

Indicator Species

Indicator organisms are pollution-tolerant and intolerant species whose presence or absence and relative abundances can give some indication of water quality at a particular site. During this investigation, a number of potentially value indicator species were identified. Taxa collected only at the two pristine sites included the caddisflies <u>Hydroptila</u>, <u>Stactobiella</u>, <u>Wormaldia</u>, and <u>Rhyacophila</u> and the stoneflies <u>Paracapnia</u> and <u>Zealeuctra</u>. Hilsenhoff (1987) considers

all of these to be pollution intolerant genera except for Hydroptila. Four additional genera, two beetles (Optioservus and Psephenus) and two odonates (Gomphus and Argia) were present at all sites except MIL. Taxa present at all sites but whose relative abundances differed substantially at pristine versus disturbed sites included the mayfly Tricorythodes, the caddisfly Agapetus, and the stonefly Isoperla.

Some of these taxa may serve as informative indicators of disturbance, but additional study is needed before selecting specific indicator species. Care must be taken to insure that the observed distributional patterns within the four sites are due to known disturbance impacts, and not to natural differences among sites.

SUMMARY AND RECOMMENDATIONS

Based on these results, a number of conclusions may be drawn regarding the level of disturbance at each site and the potential use of biological monitoring of water quality in the Buffalo National River system. First, the aquatic insect assemblages at CEC, UBV, and PON suggest that these streams (or stream reaches) are relatively "healthy" by today's standards; however, that of MIL suggests that the stream has been impacted substantially. Values of Margalef's Index indicate that Mill Creek is mildly to moderately polluted. Second, although PON may be classified as relatively "healthy," impacts have occurred. Results obtained from this site always were below those obtained at UBV. Numerous published reports and the river continuum concept suggest that natural increases in species richness and diversity should have occurred on the stream between UBV and PON. Because my results demonstrate just the opposite, I suggest that as the stream flows through Boxley Valley, it is being impacted by disturbances associated with agricultural practices. Results of physicochemical water quality monitoring indicate that the level of organic pollution has increased over the past 4 years in reaches flowing through Boxley Valley. If this trend continues, additional biotic impacts will occur resulting in a less "healthy" community of organisms. Additional study is needed to determine the impact of Mill Creek on the Buffalo River proper and to verify the results obtained in Boxley Valley.

The usefulness of biological water quality monitoring on the river appears promising. All indications suggest that a highly effective system could be established within a 2-3 year period. During this developmental phase, great emphasis should be placed on sampling from a

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variety of sites and identifying as many taxa to species as possible. For specific site to site comparisons, samples should be collected no fewer than four times yearly, preferably six. Comparisons should be made date to date and among year-in totals. Only after this more intensive sampling effort can well-founded judgements be made regarding the various indices and sampling frequency. Also, during this phase, site by site comparisons using standard benthic sampling techniques and rapid bioassessment (RBA) methods should be attempted. If RBA techniques provide good results, then they could save time and money when the monitoring program is implemented. With additional baseline data, a biotic index similar to Hilsenhoff's (1987) could be established.

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Table 1. List of taxa collected at each site. UBV, Upper Boxley Valley; PON, Ponca; MIL, Mill Creek; CEC, Cecil Creek.

TAXON	UBV	PON	MIL	CEC
Order Ephemeroptera				
Family Baetidae				
Baetis	X	X	X	X
Pseudocloeon	X	X	X	X
Family Baetiscidae				
Baetisca		X		
Family Caenidae				
Caenis anceps	X	X	X	X
C. hilaris	X	X	X	X
C. latipennis	X	X	X	X
Family Ephemerellidae				
Ephemerella		X		X
Serratella		X		X
Family Ephemeridae				
Ephemera		X		X
Family Heptageniidae				
Leucrocuta	X	X	X	X
Rhithrogena	X	X	X	X
Stenacron	X	X	X	X
Stenonema spp.	X		X	
S. femoratum	X	X	X	X
S. mediopunctatum	X	X	X	X
S. pulchellum/terminatum	X	X	X	X
S. vicarium			X	
Family Leptophlebiidae				
Choroterpes	X	X	X	X
Habrophlebiodes			X	
Leptophlebia	X			
Paraleptophlebia	X	X	X	X
Family Oligoneuriidae				
Isonychia	X	X	X	X
Family Potamanthidae				
Potamanthus		X	X	
Family Tricorythodidae				
Tricorythodes	X	X	X	X
Order Trichoptera				
Family Glossosomatidae				
Agapetus	X	X	X	X
Family Helicopsychidae				
Helicopsyche	X		X	X
Family Hydropsychidae				
Ceratopsyche	X	X	X	X
Cheumatopsyche	X	X	X	X
Hydropsyche betteni			X	X
Family Hydroptilidae				
Dibusa	X	X	X	X

Table 1. Continued

TAXA	UBV	PON	MIL	CEC
Hydroptila	X			X
Neotrichia	X			
Stactobiella	X			X
Family Lepidostomatidae				
Lepidostoma	X			
Family Leptoceridae				
Ceraclea	X			
Oecetis				X
Family Philopotamidae				
Chimarra aterrima	X		X	X
C. obscura	X	X	X	X
Wormaldia	X			X
Family Polycentropodidae				
Polycentropus	X	X	X	X
Family Psychomyiidae				
Psychomyia flavida	X	X	X	X
Family Rhyacophilidae				
Rhyacophila	X			X
Order Plecoptera				
Family Capniidae				
Allocapnia	X	X	X	X
Paracapnia	X			X
Family Choloroperlidae				
Alloperla		X		
Haploperla	X	X	X	X
Family Leuctridae				
Leuctra	X	X	X	X
Zealeuctra	X			X
Family Nemouridae				
Amphinemura	X	X	X	X
Prostoia	X	X	X	X
Family Perlidae				
Acroneuria	X	X	X	X
Neoperla (2 spp)	X	X	X	
Perlesta	X	X	X	X
Family Perlodidae				
Clioperla clio	X		X	X
Helopicus	X			
Hydroperla		X		
Isoperla	X	X	X	X
Family Taeniopterygidae				
Strophopteryx	X	X	X	X
Taeniopteryx	X	X	X	X
Order Coleoptera				
Family Dytiscidae				
Oreodytes				X

Table 1. Continued

TAXON	UBV	PON	MIL	CEC
Family Elmidae				
Dubiraphia		X		
Microcylloepus	X		X	
Optioservus	X	X		X
Stenelmis	X	X	X	X
Family Gyrinidae				
Dineutus		X	X	
Family Hydrophilidae				
Berosus			X	
Laccobius				X
Family Psephenidae				
Ectopria		X	X	X
Psephenus	X	X		X
Order Megaloptera				
Family Corydalidae				
Corydalus cornutus	X	X	X	X
Nigronia		X		X
Family Sialidae				
Sialis	X		X	
Order Neuroptera				
Family Sisyridae				
Climacia	X			
Order Diptera				
Family Ceratopogonidae		X		X
Family Chironomidae	X	X	X	X
Family Empididae				
Clinocera	X	X	X	X
Hemerodromia	X	X	X	X
Family Simuliidae				
Prosimulium	X	X	X	X
Simulium	X	X	X	X
Family Tabanidae (UNKNOWNS)	X	X	X	X
Chrysops			X	
Tabanus			X	X
Family Tanyderidae				
Protoplasa	X		X	X
Family Tipulidae				
Antocha			X	
Hexatoma	X		X	X
Limonia				X
Pilaria		X		
Tipula	X	X	X	X
Order Lepidoptera				
Family Pyralidae				
Pterophila	X	X	X	

Table 1. Continued

TAXON	UBV	PON	MIL	CEC
Order Odonata				
Suborder Anisoptera				
Family Gomphidae				
Gomphus	X	X		X
Suborder Zygoptera				
Family Coenagrionidae				
Argia	X	X		X

Table 2. Number of specimens of each taxon collected from the Buffalo River, Upper Boxley Valley between June 1990 and March 1991.

TAXON	JUN	JUL	AUG	NOV	JAN	MAR	Total
Order Ephemeroptera							
Family Baetidae							
Baetis	19	112	141			5	277
Pseudocloeon	117	24	31	22	93	85	372
Family Caenidae							
Caenis anceps		11	743	1			755
C. hilaris	1			2		3	6
C. latipennis	2	1			1	2	6
Family Heptageniidae							
Leucrocuta	13	15	92	1	2	2	125
Rhithrogena	3				1	32	36
Stenacron	1		4	2	2	9	18
Stenonema spp.	1	1	1		1		4
S. femoratum	2	1		14	22	3	42
S. mediopunctatum		61	67	58	7	5	198
S. pulchellum/terminatum	2	73	127	68	7	25	302
Family Leptophlebiidae							
Choroterpes			3				3
Leptophlebia					1		1
Paraleptophlebia	6				2	13	21
Family Oligoneuriidae							
Isonychia	9	32	214	109	16	32	412
Family Tricorythodidae							
Tricorythodes	5	4	1				10
Order Trichoptera							
Family Glossosomatidae							
Agapetus			2	11	7	60	80
Family Helicopsychidae							
Helicopsyche			1	1			2
Family Hydroptilidae							
Dibusa						3	3
Hydroptila	1		1				2
Neotrichia			1				1
Stactobiella						1	1
Family Hydropsychidae							
Cheumatopsyche	56	29	135	97	7	24	348
Ceratopsyche	1	8	6	5		1	21
Family Lepidostomatidae							
Lepidostoma	1						1
Family Leptoceridae							
Ceraclea			1				1
Family Philopotamidae							
Chimarra aterrima		1	2	3	3	13	22
C. obscura		11	23	85		22	141
Wormaldia						10	10
Family Polycentropodidae							
Polycentropus		2	5	14	2	4	27

Table 2. Continued.

TAXON	JUN	JUL	AUG	NOV	JAN	MAR	Total
Family Psychomyiidae							
Psychomyia flavida		2	22			1	25
Family Rhyacophilidae							
Rhyacophila						1	1
Order Plecoptera							
Family Capniidae							
Allocapnia				4	5		9
Paracapnia					1		1
Family Choloroperlidae							
Haploperla	1					5	6
Family Leuctridae							
Leuctra	1	5	1				7
Zealeuctra					1		1
Family Nemouridae							
Amphinemura						28	28
Prostoia					31	1	32
Family Perlidae							
Acroneuria		1					1
Neoperla (2 spp)	7	14	11	9	1		42
Perlesta	20					29	49
Family Perlodidae							
Clioperla clio					1		1
Helopicus					1		1
Isoperla				4	95	120	219
Family Taeniopterygidae							
Strophopteryx					6		6
Taeniopteryx				1			1
Order Coleoptera							
Family Elmidae							
Microcylloepus			1				1
Optioservus				2			2
Stenelmis	2	8	27	1			38
Family Psephenidae							
Psephenus	5	3	74	9		1	92
Order Megaloptera							
Family Corydalidae							
Corydalus cornutus		7	65	30		2	104
Family Sialidae							
Sialis						1	1
Order Neuroptera							
Family Sisyridae							
Climacia			1				1
Order Diptera							
Family Chironomidae	33	65	409	31	41	102	681

Table 2. Continued.

TAXA	JUN	JUL	AUG	NOV	JAN	MAR	Total
Family Empididae							
Hemerodromia	1		5	1	2		9
Clinocera						7	7
Family Simuliidae							
Prosimulium					1	1	2
Simulium	4	1		1			6
Family Tabanidae (UNKNOWNS)			3			5	8
Family Tanyderidae							
Protoplasa			2				2
Family Tipulidae							
Hexatoma		1		1			2
Tipula	1					1	2
Order Lepidoptera							
Family Pyralidae							
Pterophila		1	14	5		1	21
Order Odonata							
Suborder Anisoptera							
Family Gomphidae							
Gomphus		1	19	2		2	24
Suborder Zygoptera							
Family Coenagrionidae							
Argia				2		1	3

Table 3. Number of specimens of each taxon collected from the Buffalo River, Ponca between June 1990 and March 1991.

TAXA	JUN	JUL	AUG	NOV	JAN	MAR	Total
Order Ephemeroptera							
Family Baetidae							
Baetis	15	25	1				41
Pseudocloeon	67	6	10	9	77	85	254
Family Baetiscidae							
Baetisca				1			1
Family Caenidae							
Caenis anceps		267	317	1			585
C. hilaris	1	1		1	2		5
C. latipennis		5		4	18	19	46
Family Ephemerellidae							
Ephemerella				2	19	47	68
Serratella			7			1	8
Family Ephemeridae							
Ephemera		1	2				3
Family Heptageniidae							
Leucrocuta	4	12	22		4	5	47
Rhithrogena	5					15	20
Stenacron		5	19	20	18	34	96
Stenonema femoratum	1	3	10	15	27	18	74
S. mediopunctatum	2	70	62	75	39	73	321
S. pulchellum/terminatum		27	36	25	32	39	159
Family Leptophlebiidae							
Choroterpes		5	27				32
Paraleptophlebia	2					1	3
Family Oligoneuriidae							
Isonychia	4	23	116	77	31	61	312
Family Potamanthidae							
Potamanthus				1	3		4
Family Tricorythodidae							
Tricorythodes	3	37	229				334
Order Trichoptera							
Family Glossosomatidae							
Agapetus					1	8	9
Family Hydropsychidae							
Cheumatopsyche	6	44	130	30	21	31	262
Ceratopsyche		5	76		2	1	84
Family Hydroptilidae							
Dibusa						2	2
Family Philopotamidae							
Chimarra obscura			4	10	5	32	51
Family Polycentropodidae							
Polycentropus		1	2	1	1		5
Family Psychomyiidae							
Psychomyia flavida			2		1		3

Table 3. Continued.

	JUN	JUL	AUG	NOV	JAN	MAR	Total
Order Plecoptera							
Family Capniidae							
Allocapnia				29	1		30
Family Choloroperlidae							
Alloperla	1						1
Haploperla						18	18
Family Leuctridae							
Leuctra	1	2	15				18
Family Nemouridae							
Amphinemura						28	28
Prostoia					5	4	9
Family Perlidae							
Acroneuria		2					2
Neoperla (2 spp)		10	20				30
Perlesta	11					14	25
Family Perlodidae							
Hydroperla				2			2
Isoperla					4	41	45
Family Taeniopterygidae							
Strophopteryx					2		2
Taeniopteryx				2			2
Order Coleoptera							
Family Psephenidae							
Ectopria		1	2				3
Psephenus	1	2	173	2		6	184
Family Elmidae							
Dubiraphia		2					2
Stenelmis		43	46				89
Optioservus		3				1	4
Family Gyrinidae							
Dineutus			1				1
Order Megaloptera							
Family Corydalidae							
Corydalus cornutus			21		2	6	29
Nigronia						1	1
Order Diptera							
Family Ceratopogonidae	1	1					2
Family Chironomidae	82	288	159	55	112	160	856
Family Empididae							
Hemerodromia		9	2				11
Clinocera						5	5
Family Simuliidae							
Simulium		2			1	2	5
Prosimulium						1	1
Family Tabanidae (UNKNOWNS)		3	7			3	13

Table 3. Continued.

	JUN	JUL	AUG	NOV	JAN	MAR	Total
Family Tipulidae							
<u>Pilaria</u>				1			1
<u>Tipula</u>				1			1
Order Lepidoptera							
Family Pyralidae							
<u>Pterophila</u>		2					2
Order Odonata							
Suborder Anisoptera							
Family Gomphidae							
<u>Gomphus</u>		3					3
Suborder Zygoptera							
Family Coenagrionidae							
<u>Argia</u>			2	1	6	5	14

Table 4. Number of specimens of each taxon collected from Cecil Creek near Erbie between June 1990 and March 1991.

TAXA	JUN	JUL	AUG	NOV	JAN	MAR	Total
Order Ephemeroptera							
Family Baetidae							
<u>Baetis</u>	86	79	70			3	238
<u>Pseudocloeon</u>	89	24	1	59	144	214	531
Family Caenidae							
<u>Caenis</u> <u>anceps</u>			23				23
<u>C</u>. <u>hilaris</u>	2	7	21	1	2	4	37
<u>C</u>. <u>latipennis</u>	1	9	34	15	17	14	90
Family Ephemerellidae							
<u>Ephemerella</u>						2	2
<u>Serratella</u>					1	2	3
Family Ephemeridae							
<u>Ephemera</u>		3	14			1	18
Family Heptageniidae							
<u>Stenonema</u> <u>femoratum</u>		2		8	2		12
<u>S</u>. <u>mediopunctatum</u>		29	4	1	2	2	38
<u>S</u>. <u>pulchellum/terminatum</u>		31	14	16	20	3	84
<u>Stenacron</u>			4				4
<u>Leucrocuta</u>	10	2			5	2	19
<u>Rhithrogena</u>	1					3	4
Family Leptophlebiidae							
<u>Choroterpes</u>			1				1
<u>Paraleptophlebia</u>	7				1	14	22
Family Oligoneuriidae							
<u>Isonychia</u>	1	39	3	3	16	1	63
Family Tricorythodidae							
<u>Tricorythodes</u>		7				1	8
Order Trichoptera							
Family Glossosomatidae							
<u>Agapetus</u>	10			3	98	268	379
Family Helicopsychidae							
<u>Helicopsyche</u>		1		1	33	4	39
Family Hydroptilidae							
<u>Dibusa</u>	9					52	61
<u>Hydroptila</u>	6					7	13
<u>Stactobiella</u>					3	8	11
Family Hydropsychidae							
<u>Ceratopsyche</u>	2	5	21	5	2	2	37
<u>Cheumatopsyche</u>	22	57	48	26	53	37	243
<u>Hydropsyche</u> <u>betteni</u>		2	3	7	1		13
Family Leptoceridae							
<u>Oecetis</u>	1						1
Family Philopotamidae							
<u>Chimarra</u> <u>aterrima</u>	1	3	1	19	40	34	98
<u>C</u>. <u>obscura</u>					1		1
<u>Wormaldia</u>	1				1	1	3

Table 4. Continued

TAXA	JUN	JUL	AUG	NOV	JAN	MAR	Total
Family Polycentropodidae							
Polycentropus				1	1	5	7
Family Psychomyiidae							
Psychomyia flavida	1						1
Family Rhyacophilidae							
Rhyacophila					2	1	3
Order Plecoptera							
Family Capniidae							
Allocapnia				49	4		53
Paracapnia					2		2
Family Choloroperlidae							
Haploperla					4	26	30
Family Leuctridae							
Leuctra	250	171	20				441
Zealeuctra						1	1
Family Nemouridae							
Amphinemura					2	136	138
Prostoia					28	1	29
Family Perlidae							
Acroneuria	5	8	2				15
Perlesta	10					60	70
Family Perlodidae							
Clioperla clio						3	3
Isoperla				12	13	342	367
Family Taeniopterygidae							
Strophopteryx					1		1
Taeniopteryx				2			2
Order Coleoptera							
Family Dytiscidae							
Oreodytes	1						1
Family Elmidae							
Optioservus	8	2	9	22	13	29	83
Stenelmis	1		2	1	6		10
Family Hydrophilidae							
Laccobius			1				1
Family Psephenidae							
Ectopria						1	1
Psephenus	4	1	19	4	7	22	57
Order Megaloptera							
Family Corydalidae							
Corydalus cornutus		8	6	2	2	2	20
Nigronia			3				3
Order Diptera							
Family Ceratopogonidae	1				1		2
Family Chironomidae	283	120	138	45	76	104	766

Table 4. Continued

TAXA	JUN	JUL	AUG	NOV	JAN	MAR	Total
Family Empididae							
Clinocera						17	17
Hemerodromia		1	2		1		4
Family Simuliidae							
Prosimulium					39	7	46
Simulium	2	1				15	18
Family Tabanidae (UNKNOWNS)						12	12
Tabanus		1		3	1		5
Family Tanyderidae							
Protoplasa						5	5
Family Tipulidae							
Hexatoma	2		1			1	4
Limonia				1			1
Tipula					2		2
Order Odonata							
Suborder Anisoptera							
Family Gomphidae							
Gomphus		3	2		10	1	16
Suborder Zygoptera							
Family Coenagrionidae							
Argia					1		1

Table 5. Number of specimens of each taxon collected from Mill Creek near Pruitt between June 1990 and March 1951.

TAXA	JUN	JUL	AUG	NOV	JAN	MAR	Total
Order Ephemeroptera							
Family Baetidae							
Baetis	91	383	281			1	756
Pseudocloeon	218	4	10	57	118	278	685
Family Caenidae							
Caenis anceps	9	8	74				91
C. hilaris	2			1			3
C. latipennis						1	1
Family Heptageniidae							
Leucrocuta	6					3	9
Rhithrogena						2	2
Stenacron	3	3		2			8
Stenonema spp.					2		2
S. femoratum	1			1	2		4
S. mediopunctatum			25		6	1	32
S. pulchellum/terminatum	4	2	22	4	23	10	65
S. vicarium					2		2
Family Leptophlebiidae							
Choroterpes	10	3	4				17
Habrophlebiodes	7						7
Paraleptophlebia				11			11
Family Oligoneuriidae							
Isonychia	18	8	66	141	48	20	301
Family Potamanthidae							
Potamanthus			9		1		10
Family Tricorythodidae							
Tricorythodes	33	3	10				46
Order Trichoptera							
Family Glossosomatidae							
Agapetus						2	2
Family Helicopsychidae							
Helicopsyche				2	4	1	7
Family Hydropsychidae							
Ceratopsyche		22	2	1			25
Cheumatopsyche	35	258	107	4	25	7	436
Hydropsyche betteni	4		2			1	7
Family Hydroptilidae							
Dibusa angata						3	3
Family Philopotamidae							
Chimarra aterrima	1	5	6	7	2	2	23
C. obscura	2	58	8				68
Family Polycentropodidae							
Polycentropus	1						1
Family Psychomyiidae							
Psychomyia flavida			3				3

Table 5. Continued

TAXA	JUN	JUL	AUG	NOV	JAN	MAR	Total
Order Plecoptera							
Family Capniidae							
Allocapnia				175	9	2	186
Family Choloroperlidae							
Haploperla					1	1	2
Family Leuctridae							
Leuctra	39	2	11				52
Family Nemouridae							
Amphinemura						24	24
Prostoia					4		4
Family Perlidae							
Acroneuria	9				3	1	13
Neoperla (2 spp)		2					2
Perlesta	16					10	26
Family Perlodidae							
Clioperla clio					1		1
Isoperla						8	8
Family Taeniopterygidae							
Strophopteryx					2		2
Taeniopteryx				9			9
Order Coleoptera							
Family Elmidae							
Microcylloepus		1					1
Stenelmis	10	4	4	1		3	22
Family Gyrinidae							
Dineutus	3	5					8
Family Hydrophilidae							
Berosus						1	1
Family Psephenidae							
Ectopria					1	2	3
Order Megaloptera							
Family Corydalidae							
Corydalus cornutus		39	88		1	2	130
Family Sialidae							
Sialis	3						3
Order Diptera							
Family Chironomidae	229	131	29	264	328	68	1049
Family Empididae							
Clinocera						3	3
Hemerodromia		11	1		15	2	29
Family Simuliidae							
Prosimulium		11			24	28	63
Simulium	3			6	1	13	23
Family Tabanidae (UNKNOWNS)					1	28	29
Chrysops	1						1
Tabanus			2		1		3

Table 5. Continued.

TAXA	JUN	JUL	AUG	NOV	JAN	MAR	Total
Family Tanyderidae							
Protoplasa						1	1
Family Tipulidae							
Antocha	1				1		2
Hexatoma					1		1
Tipula					2		2
Order Lepidoptera							
Family Pyralidae							
Pterophila						1	1

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